Introduction to Energy Efficiency in Further and Higher Education

BEST PRACTICE PROGRAMME

Energy Efficiency Office
DEPARTMENT OF THE ENVIRONMENT

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INTRODUCTION

1.1 Who this guide is intended for

This guide is aimed at university bursars, site engineers, facilities managers and others who have responsibility for energy use in university and further education buildings.

It is intended to introduce the steps that anyone responsible for energy needs to take in order to control and reduce energy consumption. It shows how to gain an understanding of energy use in universities and further education colleges and indicates the methods by which savings are likely to be made.

1.2 Use of the guide

This guide is one of a series for different types of building. A full list of titles is given in section 9.4; make sure that you have the guide most suited to your needs.

If you are unfamiliar with energy management, you should start with section 2, Energy Management, in order to get an overview of the subject.

- The subsequent sections concern creating and following an action plan (section 3) and implementing measures to achieve energy savings (section 4). Sections 5 to 7 describe methods for assessing energy use in further education buildings.
- The case studies (section 8) give examples of buildings where energy saving measures have been successfully implemented.
- Section 9 lists further sources of help and information, including addresses for obtaining copies of the information referred to throughout the guide.

More experienced energy managers or consultants may use the action plan (section 3), or the suggested measures (section 4) as aide-memoires. They may also use the method for calculating performance indices described in section 6 and appendix 1.

A manager responsible for energy on a number of different sites may wish to distribute the guide to the person responsible for energy management in each department or facility.

1.3 Environmental benefits of energy efficiency

Most of the energy used today originates from fossil fuels (gas, oil and coal). Burning fossil fuels emits pollutants, including gases that cause acid rain, and carbon dioxide. As carbon dioxide and other gases build up in the atmosphere, more of the sun's heat is trapped (the greenhouse effect). This could result in the earth becoming hotter (global warming), which may also increase the risk of storms, coastal flooding and drought. Using energy more efficiently is one of the most cost effective means of reducing emissions of carbon dioxide and also helps to conserve finite reserves of fossil fuels.

1.4 Financial benefits of energy efficiency

Energy is a large controllable cost in running universities and further education buildings. Using simple and cost effective measures, fuel bills in these buildings could be reduced by about 20%. Further savings are possible in new construction and when buildings are refurbished or their services replaced.

Well designed and efficiently managed services not only result in energy savings, but also in an improved and more comfortable working and living environment for students and staff. This can give rise to better productivity and reduced absence due to sickness.

Efficiently run buildings also require less manpower to service complaints, providing savings additional to the reduced costs of energy.

1.5 Acknowledgements

This guide was prepared for the Energy Efficiency Office (EEO) by Target Energy Services Ltd. The EEO gratefully acknowledges the assistance given by the following organisations in providing information:

Building Energy Solutions

Building Research Energy Conservation Support Unit (BRECSU)

Cambridge University

Hampshire County Council

Oxford Brookes University

Southampton Technical College

University of York

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ENERGY MANAGEMENT

2.1 Energy efficiency - a management issue

The aim of energy management is to ensure that energy use and energy costs are as low as possible while standards of comfort, service and productivity are maintained or improved. This requires somebody to be directly responsible for energy efficiency, even if this is only a part of their job:

- As a rule of thumb, organisations or sites with an energy bill over £1 million may justify the employment of a full time energy manager. Otherwise, energy management will normally be combined with other responsibilities.
- Each building or department should have someone responsible for energy management.
- In larger organisations, energy efficiency should also be managed centrally.
- Energy efficiency must be strongly supported at the highest levels with the authority and resources needed for initiatives to be effective.

Encourage your management board to sign up to the EEO's Making a Corporate Commitment campaign if it has not already done so (see section 9.5).

The duties and functions of an energy manager are discussed here. Section 3 includes a suggested action plan which can be used to get things moving.

2.2 Actions and measures to save energy

One of your main activities should be to identify areas of energy waste and implement energy saving measures to reduce them. Some waste is simple to diagnose and to correct, for example lighting left on all night in unoccupied areas. Other waste may be more difficult to identify and take more expertise or resources to correct (see section 4).

2.3 Controlling energy use

To control energy consumption and costs, regular and reliable records of energy use should be maintained. Such records will help to identify changes in energy costs and consumption. It is especially important that major buildings, facilities and residential halls are separately metered and the users separately billed to control energy costs (see section 4.1). This is commonly called monitoring and targeting or M&T. The simplest arrangement is a form which can be filled in regularly for each fuel, recording monthly energy use. Alternatively, systems can be based on a computer spreadsheet, or commercially available software systems can be purchased. Computer based systems are essential for effective monitoring of a large estate or site.

An M&T system should:

- Record energy consumption and any other factors that affect energy use (building usage, weather, out of term or after hours use, etc).
- Compare your site's or building's energy use to previous years, to other sites or buildings, or to yardsticks representing typical or target energy performance.
- Alert you to sudden changes in energy use patterns as soon as possible, so that any increase can be investigated and corrected if appropriate.
- Produce regular summary reports, especially if it is a large site, to confirm performance and show savings achieved overall.

If fuel bills are not available or some are missing, then duplicates can usually be obtained on request from the relevant fuel supply company. Meters should be checked every few months to ensure that billed readings are correct. In shared or multi - meter sites ensure you are being billed for your use; label your meters.

For further information see:

EEO Practical Energy Saving Guide For Smaller Businesses.

Example recording of monthly electricity use

Period: *JAN-DEC 92* Completed by: *NJK* Date: *10.2.93*

Meter Reading Date	kWh Used	Cost £
8.1.92	39,700	2756.29
5.2.92	38,700	2653.65
5.3.92	31,500	2200.35
9.4.92	25,000	1584.02

2.4 Cost centres

It is preferable on multi-building sites to introduce sub-metering in order to monitor energy use in particular areas and target resources at high energy areas. It may be possible to use this information to set up cost centres and hence charge academic departments for their consumption as a means of motivating departmental heads.

- Introduce cost centres based on academic departments in order to highlight what they spend on energy. This can be done by sub-metering.

- Residential buildings should be separately metered as these have a high energy usage. They are often used outside the academic year to house conference delegates and the cost of energy should be included in the conference fee.

2.5 Getting on the right tariffs

Making sure that fossil fuels and electricity are purchased at the cheapest rates is increasingly important. Considerable cost savings are sometimes possible by changing to more suitable tariffs for electricity, or by making alternative supply arrangements.

Tariff savings usually incur little or no initial cost and may be used to help finance measures to reduce energy costs further. Reviewing tariffs should therefore be one of your first actions.

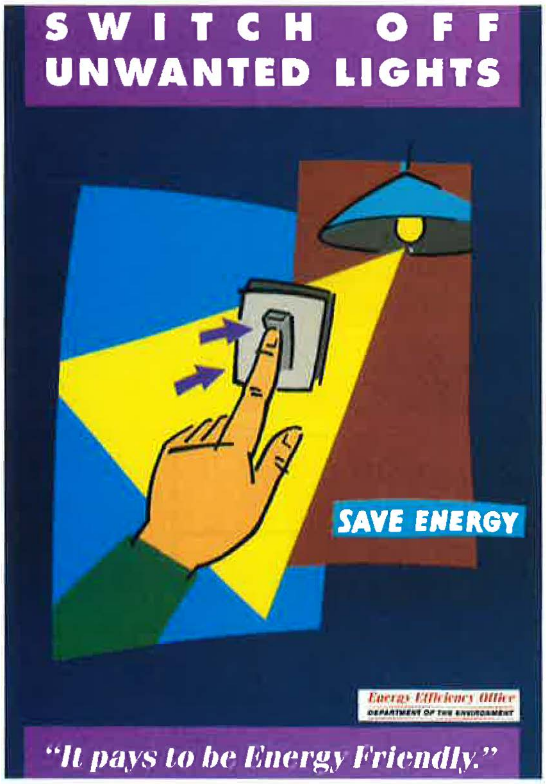
- Seek alternative electricity tariffs from your existing supplier.

- Consider using other electricity suppliers in the contract market when the supply is for more than 100 kW (representing a bill of around £30,000 a year).

- Consider a different supplier for oil, or for gas supplies over 70,000 kWh a year (representing a bill of around £1,000 a year).

- For large sites with complicated tariffs and load patterns, it may be worth employing a tariff consultant, although be aware of consultants' costs (contact Energy Systems Trade Association (ESTA) or the Major Energy Users Council, see section 9.9).

Energy Efficiency Poster



For further information see:

EEO Fuel Efficiency Booklet 9 - Economic use of electricity in buildings.

2.6 Extended periods of use

Holding out of term conferences and out of hours activities can significantly increase a site's energy consumption. Costs can be controlled by limiting building access and providing local heating only. For individual classes this could be by portable electric or gas fires and in residential blocks dedicated local hot water boilers.

Extending the hours of use in a teaching building by only 2 hours is likely to increase energy costs by about 10%. It is therefore important to consider this when deciding to increase the use of buildings.

If the set-up of the heating system allows, heating should be confined to those buildings that are used out of normal hours. On days that the buildings are not required outside normal hours, the heating controls should be set for normal daytime use only.

These principles can also be used to advantage during holiday periods. Heating all the teaching buildings to full temperature for small numbers of staff will waste energy. It may be possible to turn off domestic hot water systems during these periods.

2.7 Cleaning

Whenever possible, cleaning should be carried out immediately before or after teaching buildings are occupied, when the pre-heating or residual heat can provide adequate background heating. During the heating season, if cleaning has to be done at other times, it can prove expensive to heat the whole building for a small number of people.

Cleaning staff should be asked to keep windows and doors closed at all times. This is particularly important if cleaning is done during the pre-heating period when the system is bringing room temperatures up to comfort level. Cleaning staff should be asked to limit their use of electricity by switching lights on and off as they move from room to room. This also applies to security staff.

2.8 Motivating staff and students

The greatest possible savings can only be achieved with the cooperation of staff and students. Foster their support and give them every chance to participate in energy saving initiatives. Feed back information to staff and students on the results of these initiatives.

Activities could include:

- Providing information about why energy conservation is important, describing practical and environmental benefits

- Setting up an incentive scheme

- Stressing that most energy is used by staff and students - for lighting, equipment and for maintaining comfortable conditions

- Encouraging staff to switch off equipment and lighting when it is not needed, by

providing information and training on how to operate systems and controls, through stickers, posters and articles in student and staff magazines

- Relating energy use at college to energy use at home.

You should monitor the savings achieved and publicise them to help motivate staff and senior management. Obtaining capital investment for future energy efficiency measures may depend on demonstrating the cost effectiveness and the environmental benefits of measures that have already been completed.

For further information see:

EEO Good Practice Guide 84 - Managing and motivating staff to save energy.

2.9 Responsibilities in larger sites

At larger sites a number of groups should be involved in energy management:

- Senior management
- Local or departmental management
- Student representatives
- Facilities management
- Plant operators
- Security staff
- Residential Hall Wardens
- Maintenance contractors.

You should have regular contact with all of the above and the staff who use individual buildings. You should find out about factors relating to staff and students' comfort, including:

- How plant and equipment controls are set and who is responsible for their adjustment
- How comments from students and staff are acted on - especially those reflecting dissatisfaction.

2.10 Energy management in larger organisations

In larger universities and colleges, a central energy manager may be responsible for many separate locations. He or she will have a different role from the person responsible for energy at a local level, which is not addressed in detail here.

For further information see:

EEO General Information Report 12 - Organisational aspects of energy management

EEO General Information Report 13 - Reviewing energy management

Making a Corporate Commitment - various guides (see section 9.5)

2.11 New and refurbished property

Energy efficiency measures are most cost effective when installed in new or refurbished buildings, or while replacing equipment which is at the end of its normal life. New items of equipment which are required anyway should be as efficient as possible. Additional items to improve energy efficiency can be installed most cheaply during other building work. These special opportunities to incorporate energy efficient design are rare and should not be missed.

You should be involved in decisions about new or refurbished property and should not just be brought in to correct high energy use following decisions made by others. Your knowledge of how the building is used should be drawn on when specifying appropriate levels of services and controls.

When moving site or refurbishing a building, take the opportunity to select or specify:

- Energy targets
- Systems which are suitably simple and within the capabilities of the occupants to manage
- High efficiency of major plant and equipment such as boilers or main lighting systems
- Good levels of insulation
- Appropriate controls for the anticipated pattern of use
- Suitable metering and monitoring facilities
- Information, advice and training for staff in the use of new systems.

Refurbishment offers a rare opportunity to incorporate many energy efficiency measures.

2.12 Getting help

Sources of further information are described and listed in section 9.

To obtain further information about possible energy saving measures (see section 4), contact relevant manufacturers, installers or service providers who will advise you of the features of their products. Make sure that these features are relevant and appropriate to your requirements. Gas and electricity suppliers can also offer advice.

If time is not available or if discussions with a selection of competing suppliers do not provide a consistent picture, it may be worth hiring a professional consultant to provide advice or to conduct an energy survey.

If the availability of finance and management time is a problem for opportunities requiring substantial investment, contract energy management (CEM) organisations may provide a solution - they offer a comprehensive service including finance and management responsibility. ESTA can provide a list of companies (see section 9.9).

For further information see:

Choosing an Energy Efficiency Consultant (EEO).

ACTION PLAN

This flow diagram presents a step by step procedure to achieve cost savings in a building or a single site by bringing energy consumption and cost under control. It refers to other parts of this document for further guidance.

Produce your own action plan with these headings, showing specific actions and projects, each with target completion dates. The plan should be consulted frequently and reviewed annually.

It can sometimes be useful to set up an energy commitee and introduce cost centres.

1. Confirm who is responsible for energy management (it may be you) and seek senior management support

2. Obtain energy bills and start recording and assessing billed energy consumptions — **See section 2.3**

3. Check fuel and electricity tariffs and change where appropriate — **See section 2.5**

4. Undertake an initial 'walk around' of the premises to identify avoidable waste — **Use checklist in section 4.1**

5. Assess building energy performance and scope for initial energy saving measures — **See sections 5 and 6 for building performance index**

6. Consider technical and management responsibilities — **See sections 2.7-2.10**

7. Plan and start a programme of longer term energy saving measures — **See section 4 .3**

8. Plan and start a programme of motivating staff and students — **See section 2.8**

9. Carry out a more detailed energy survey and obtain advice when appropriate — **Refer to measures in section 4 and analysis in section 7**

10. Plan and implement identified measures

11. Reinforce motivation and encouragement of staff and students

12. Review progress, assess savings and revise plans

Ongoing energy management

MEASURES TO ACHIEVE ENERGY SAVINGS

4.1 Initial measures

On most sites it is possible to make some savings by using the existing buildings and equipment as efficiently as possible. No financial investment is needed; instead, a check on how the site is being used may reveal areas where plant and equipment can be turned off when it is not needed, or where the level of service can be reduced without affecting the comfort of staff and students.

Some opportunities may be easy to identify and implement, such as altering thermostats or timeclocks. Others, such as turning lights off when rooms are not being used, may require the cooperation of building occupants. Departments can help to save energy by grouping evening lectures, for example, into a few buildings rather than using the whole site. Motivating everybody to help is therefore important, although a long term task. The list below indicates the type of items to check in an initial assessment of 'good housekeeping' opportunities. An exercise to review energy purchasing tariffs (see section 2.5) should be carried out at the same time.

Checklist of Initial Energy Saving Measures

Space and water heating

- Consider fuel switching (if your boiler can operate using more than one fuel).
- Check that time switches are set to the minimum period and ensure that room thermostats and radiator controls are on minimum settings commensurate with comfort conditions.
- Consider switching off heating and domestic hot water at night in residential buildings.
- Ensure that only occupied areas are heated, and that heating is off or reduced in non-working hours.
- If you have a building energy management system (BEMS), check that it is operating correctly and ensure that operators are trained to use it effectively.
- Reduce temperature of stored domestic hot water by turning down the thermostat to a minimum of 60°C, but no lower because of the risk of Legionella.
- Make sure that pumps are running only when required.
- Isolate buildings from the district heating main when they are not in use.

Lighting

- Ensure that someone is responsible for switching off in each room or area when not in use.
- Make the best use of daylight by keeping windows and roof lights clean and by using working areas near windows where possible; encourage staff and students to turn off lights when daylight is good.
- Investigate existing lighting controls to see if the hours of use of artificial lighting can be reduced.
- Install 'task' lighting where this means that background artificial lighting levels or hours of use can be reduced.
- Avoid excessive lighting levels and hours of use in corridors. Where fluorescent lighting is used, it may be possible to reduce the number of tubes in luminaires.

Ventilation

- Ensure the main ventilation plant and toilet extractor fans are switched off outside occupancy hours.
- Check that windows are not being opened to avoid overheating during winter.
- Ensure kitchen fans are switched off when no cooking is taking place.
- Ensure that fume cupboard fans are not left running unnecessarily.

Air conditioning

- Set temperature controls for cooling to 24°C or higher - lower settings require more cooling energy and may be 'fighting' the heating.
- Where the design permits, ensure heating and cooling are not on at the same time in the same part of the building (the advice of a consultant or on site services engineer may be needed).
- Make sure that refrigeration plant such as chilled water systems do not run unnecessarily.
- Ensure that fans and pumps do not run when not required.

Equipment

- Encourage staff and students to turn off equipment when it is not being used, particularly at lunchtime and at the end of the working day.
- Ensure that laboratory equipment is not left running unnecessarily and make research staff aware of the costs of running this equipment.
- Control services such as compressed air and vacuum systems in relation to requirements.

Controls

- Ensure all controls are labelled to indicate their function and, if appropriate, their new reduced settings.
- Establish responsibilities for control setting, review and adjustment.
- Ensure local controls cannot be tampered with by students.

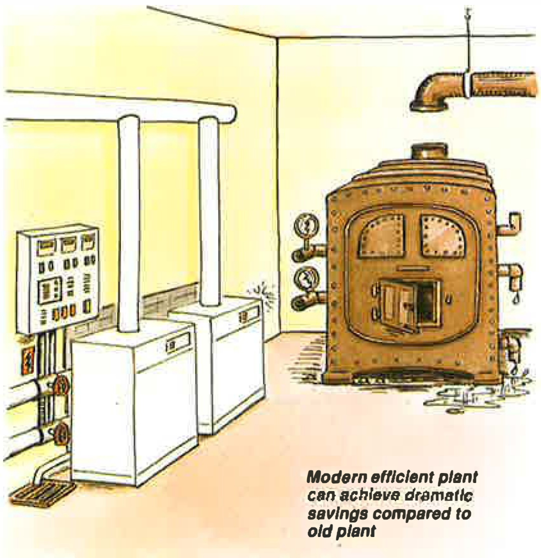
Building fabric

- Ensure all insulation is in a state of good repair.

4.2 Maintenance

Regular maintenance is a prerequisite to controlling energy costs and is also essential for maintaining a healthy environment in buildings. A maintenance programme should include:

- Replace filters at the manufacturer's recommended intervals and keep heat exchanger surfaces, grilles and vents clean in order to allow unobstructed flow of air
- Check plant operation and controls regularly
- Ensure that all motorised valves and dampers fully open and close without sticking
- Check that thermostats and humidistats are accurate
- Check calibration of controls
- Service the boiler plant and check combustion efficiency regularly
- Look for water and steam leaks and carry out repairs where necessary
- Clean windows to maximise daylighting
- Replace 38mm diameter fluorescent tubes in switch start fittings with 26mm diameter high efficiency triphosphor tubes as the former expire (see diagram on page 10)



Modern efficient plant can achieve dramatic savings compared to old plant

- Clean lamps and luminaires regularly and replace at the manufacturer's recommended intervals.
- Check district heating mains insulation for damage and ensure it has not become waterlogged.

4.3 Longer term measures

There will almost certainly be items of equipment or insulation which could be replaced with more efficient alternatives. The main areas for savings, starting with the most cost effective, are:

- Control systems
- Lighting and equipment
- Heating and air conditioning plant
- Building fabric.

Care is required in deciding which measures to implement and the most effective way of carrying them through. In the first instance, measures should be undertaken which have as many of the following features as possible:

- Worthwhile energy and cost savings
- Low capital cost
- Short period to repay initial cost
- Little technical knowledge required
- Little or no extra maintenance
- Little or no disruption to normal operations.

Further information is given in references listed in section 9 - note particularly:

EEO Fuel Efficiency Booklets:
1 Energy audits for buildings
8 The economic thickness of insulation for hot pipes
10 Controls
12 Lighting

EEO Good Practice Guides:
35 Energy efficient options for refurbished offices
46 Heating and hot water systems in offices

Energy Efficient Lighting in Buildings. A THERMIE Maxibrochure.

Assessing costs of measures

The cost effectiveness of an energy efficiency investment can be expressed as the initial cost divided by the monthly or annual cost savings - the simple payback period.

More sophisticated appraisal techniques for comparing different investments, such as 'discounted cash flow' methods, are sometimes used in larger organisations and for major investments. If these are needed, advice should be sought from those who use these methods.

If energy-saving initiatives are taken during refurbishment or when moving site, capital cost is often substantially reduced and interference with normal working practices is kept to a minimum.

For measures included during replacement or refurbishment, the initial cost (for calculating the payback period) is only the over-cost: for example, the extra cost of a high efficiency 'condensing' boiler compared with a conventional boiler. This reduces payback periods and increases cost-effectiveness.

In some cases, energy efficiency measures can reduce overall capital costs, such as using natural ventilation which avoids the need for air conditioning.

Where shortage of funds and/or lack of expertise is holding up promising measures, it may be worth considering contract energy management as described in section 2.12.

Measures can be split into those which require limited attention such as insulation, and those which require management time to ensure that they continue to be effective, such as building energy management systems. For the latter, manageability is as important as the potential for energy savings, and should be a prime consideration in the design.

LIGHTING

Lighting is usually one of the largest energy costs in university and further education buildings, and good savings can be achieved by ensuring that lighting equipment and its controls and management are of a high standard.

The energy used for lighting depends upon the energy consumption of the lamps and the hours of use. The most efficient systems are well designed, and have efficient lamps and fittings which provide the required level of illuminance (without over-lighting). They have controls which enable the lights to be switched off when they are not required, whether because a space is not being used or because there is sufficient daylight.

All new lighting in areas with VDU equipment must comply with the Health and Safety (Display Screen Equipment) Regulations 1992 which implement the 1990 European Directive 90/270/EEC. Lighting for existing workstations must comply by 31 December 1996. Wherever lighting is upgraded, it offers an opportunity to select the most energy efficient options.

Luminaires, left to right: recessed mirrored reflector with louvres, batten fittings, opal, and prismatic diffusers.

Photographs supplied by Philips and Fitzgerald.

Some types of lamps, in order of increasing efficiency, are:

- 'Domestic' tungsten bulbs - very inefficient; should usually be replaced
- Tungsten spotlights - used for display lighting; even the most efficient lamps are much less efficient than fluorescent lamps
- Compact fluorescent lamps - efficient replacements for tungsten bulbs, although not as efficient as modern tubular fluorescent lamps
- Fluorescent tubes - used in offices, lecture theatres and corridors and should also be used in residential buildings
- Metal halide and sodium discharge lamps - these vary in efficiency depending on type (most are more efficient than fluorescent tubes). Sometimes used in uplighters; well suited to lighting large areas such as car parks.

Figure 4.1 Typical relative energy consumption

lamp type	typical energy consumption relative to tungsten bulbs for similar levels of lighting (%)
tungsten filament bulb	100
tungsten halogen spotlight	70
high pressure mercury (MBF)	22
compact fluorescent with electronic ballast	18
metal halide (MBI)	15
high pressure sodium	11
low pressure sodium	7
Fluorescent tubes:	
(1) choke & starter control gear with 38mm diameter tubes	18
(2) as 1), but 26mm diameter high efficiency triphosphor tubes	16.5
(3) as 2), but with electronic ballast	13

Tungsten bulbs typically have a life of about 1,000 hours, while fluorescent and discharge lamps typically last for 8,000 hours or more. Removing tungsten bulbs therefore gives substantial savings in maintenance costs in addition to energy savings.

Typical levels of energy consumption of different types of lamp, expressed as a percentage relative to tungsten lamps, are given in figure 4.1.

These figures give an indication of the typical savings which may be made by replacing lamps with more efficient alternatives. For example, replacing an old inefficient tubular fluorescent system (1) with a modern efficient system (3) would reduce energy consumption by a factor of 13/18, a reduction of about 30%.

As well as lamps, light fittings (luminaires) contain a number of other elements, including:

- Diffusers or louvres - these are designed to give a good distribution of light without glare. Luminaires with prismatic and especially opal diffusers are less efficient than those with reflectors.
- Control gear - fluorescents and other discharge lamps need control gear to strike

Compact fluorescent lamps

up and maintain light output. Old fluorescent luminaires have chokes and starters; modern electronic controls (ballasts) are more efficient.

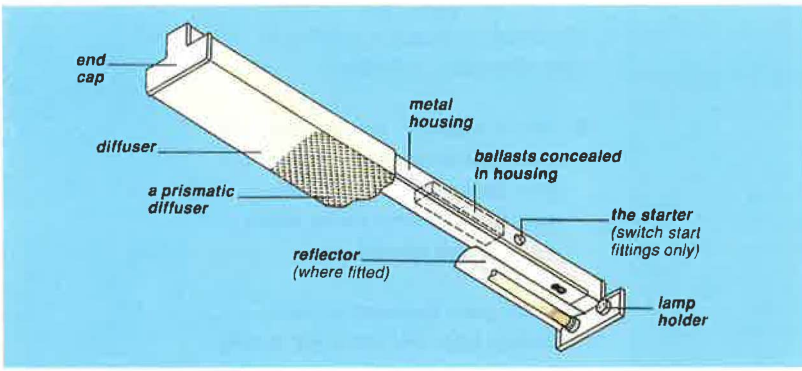
Lighting controls should be used to ensure that, as far as possible, lights are off when they are not needed. It is important that staff should have control over their levels of lighting. If automatic controls are used to turn lights on or off, staff should be able to over-ride them using manual switches. Automatic controls are most effective in open plan areas and corridors, where lights tend to be left on all day if there is no automatic switching off.

Lighting controls include:

- Time controls - allow any group of lights to be switched on or off automatically at set times of the day
- Presence detectors - automatically switch lights on when somebody enters a space, and off again after the space is vacated
- Daylight detectors - allow groups of lights to be switched off or on according to the level of daylight. Some lights can also be dimmed as daylight levels alter.

LIGHTING MEASURES

- Replace tungsten lamps with compact fluorescent lamps or, better, with tubular fluorescent lamps.
- Replace tungsten spotlights with low voltage tungsten halogen lamps.
- Replace existing control gear in fluorescent fittings with electronic, high frequency ballasts.
- Replace diffusers in tubular fluorescent fittings with reflectors and reduce the number of tubes if possible.
- If light fittings are over 15 years old, replace with new efficient fittings and consider installing new lighting controls.
- Use metal halide or sodium discharge lamps for outside areas such as car parks.
- Improve lighting controls, including:
  - local manual switching, such as pull cords on lights, so that staff and students have control over their local lighting, particularly in open plan areas
  - time controls for teaching or office areas which, for example, switch off at lunch time and the end of the day (ensure lights are switched off in stages)
  - time controls or daylight detection controls for external lighting
  - presence detection controls for corridors and stairs (excluding emergency lighting) and for areas which are infrequently used, such as stores
  - daylight detection controls for lighting adjacent to windows.



The parts of a fluorescent light fitting

HEATING SYSTEM

The cost of providing heat for space heating or hot water depends on the cost of the fuel used, the efficiency of conversion of fuel to heat, and the extent of the distribution losses in supplying the heat when and where it is needed.

Fossil fuels such as gas, oil or coal are usually burnt in a boiler and the heat is transferred to a heating system. Boilers have varying seasonal efficiencies - old boilers may convert less than 50% of the energy content of the fuel into heat in the heating system. The most efficient systems include gas condensing boilers and combined heat and power (CHP) installations. Condensing boilers can achieve seasonal efficiencies of over 90% and can be used with most existing heating systems. They ought to be considered whenever boilers are replaced. CHP should also be considered wherever there is a continuous demand for heat and power.

Heat is lost from the heating system through ductwork, pipework, valves and hot water storage tanks. Pipe runs should be short, and all parts of the system well insulated. Heat should only be supplied to a space or to produce hot water where and when it is needed. Where possible, large boilers should not be operated to meet small loads, as the efficiency will be very low.

Effective heating controls are essential. Types of control include:

- Simple time control: a time switch that turns heating on and off at a fixed time each day - seven day time switches allow for variable occupancy during the week
- Optimum start control: switches the heating on so that the building reaches the desired temperature just in time for occupation
- Weather compensation: varies the heating according to the outside temperature
- Room thermostat: keeps the temperature in a room to a required level

- Thermostatic radiator valves (TRVs): regulate the flow of hot water through the radiators in a room in order to maintain a local temperature
- Zone control: controls parts of a building or site according to the local needs for heat
- Boiler sequence control: enables only the number of boilers required to meet the system demand.

The 1990 Building Regulations specify that new non-domestic buildings should have time controls and weather compensation, room thermostats or TRVs, and that large buildings should also have optimum start control.

HEATING MEASURES

- Install zone controls so that areas of the building/site with different heating requirements (in particular, teaching areas that are used in the evening) can be controlled separately.
- Fit TRVs in rooms which are prone to over-heating, due to solar gain, for example.
- Upgrade heating controls to include a seven day programmable timer, optimum start control and weather compensation as a minimum.
- Where small volumes of domestic hot water are required a long way from the main heating plant, consider installing local instantaneous water heaters.
- Install spray taps where possible.
- Insulate hot water tanks and boilers, and all pipework, valves and flanges which do not provide useful heat to occupied spaces, particularly on district heating mains.
- Replace an old boiler installation with one that provides a minimum seasonal efficiency of at least 80%, preferably including at least one condensing boiler. Specify multiple boilers with a sequence controller rather than one large boiler in installations over 100kW, with the most efficient boiler leading the firing sequence.
- Ensure that boilers can only run when there is a heat demand. Unnecessary firing is known as "dry-cycling" and is often remedied by correctly wiring the boiler thermostat into the control system. In multi-boiler installations, wide band thermostats often overcome dry-cycling.
- Install a heater other than the main boiler to produce domestic hot water, and turn off the main boiler during the summer.
- Consider introducing radiant heating systems in larger spaces such as workshops, high bay research facilities and sports halls.
- Consider decentralising district heating mains and installing local condensing boilers and/or consider installing CHP to provide the base load on the district heating system.

COMBINED HEAT AND POWER

CHP plant provides both electricity and heat. The fossil fuel supplied to the plant displaces high cost electricity. As the heat which is inevitably produced is used for heating rather than being wasted, it is a more energy efficient means of generating electricity than conventional power stations. Overall efficiencies are typically 60-80 %.

It is essential that the CHP plant is sized correctly in order to maximise the hours it runs and hence the savings achieved. This generally means matching the plant to the base load energy demands in the facility. CHP is usually cost effective if it runs for greater than 4,500 hours/year.

CHP should be installed under a long term service contract with the supplier. The contract should specify the periods when essential maintenance should take place. It should also include penalty clauses for non compliance to reduce the risk of increased maximum demand tariff charges which would occur when the CHP plant was not running, even for the shortest period. This is particularly important during winter when maximum demand charges are at their highest. Any prolonged stoppage will also result in an increase in electrical consumption leading to higher overall energy costs.

MECHANICAL VENTILATION AND AIR CONDITIONING

Mechanical ventilation provides air which is filtered and heated. Air conditioning additionally provides cooling and humidity control.

Pumps and fans consume a considerable amount of energy; in air conditioned buildings they consume at least half, and often more, of the total energy used for air conditioning.

Cooling is usually provided by an electrically driven refrigeration plant. Cooling systems should be controlled and insulated in the same way as heating systems. The savings will be proportionally higher as cooling is considerably more expensive to produce than heat.

MECHANICAL VENTILATION AND AIR CONDITIONING MEASURES

- Ensure that fans, pumps and heater batteries for lecture theatre ventilation plant are off outside teaching hours (but do not override frost protection).
- Install variable speed controls on fans and pumps; these allow motor speeds to be controlled according to the demand instead of running at full power continuously.
- Ensure that controls are set or improved to avoid both heating and cooling air at the same time.
- Ensure that air conditioning systems make use of outside air for 'free cooling' whenever possible.
- When heating or mechanical cooling is required, ensure that the proportion of air recirculated within the building is as high as possible within the requirements for minimum fresh air rates.

- If humidifiers are being specified use ultrasonic humidification. (Ensure that adequate precautions are taken to avoid legionella)

- Explore the opportunities for heat recovery from any source of warm exhaust air but bear in mind the increase in pump and fan power that will be required.

BUILDING FABRIC

Simple roof insulation and draught proofing are usually cost effective at any time, but most other building fabric measures are most cost effective when they form part of general maintenance or refurbishment.

Caution: Insulation measures should be checked for condensation and water penetration risks. Double glazing may reduce air infiltration rates to a level where additional ventilation becomes necessary.

BUILDING FABRIC MEASURES

- Insulate roof voids.

- Draught proof around windows and doors.

- Fit secondary glazing.

- Install cavity wall insulation or internal or external insulation.

- Reduce excessive glazing areas by replacing the glass with insulated wall panels.

- If windows are being replaced, fit multiple glazing, preferably with low emissivity glass which reduces heat loss in winter.

BUILDING ENERGY MANAGEMENT SYSTEMS (BEMS)

BEMS are computer-based systems which automatically monitor and control a range of building services such as heating, air conditioning, ventilation and sometimes lighting. They may also provide data on energy performance to enable energy savings to be targeted. They are most cost-effective in large sites which have complex building services. They can also be used as an aid in allocating energy use to cost centres in a large multi building site.

Caution: A BEMS should be considered as an aid to management and not a substitute for it, and it is important that someone manages it to ensure that it operates effectively.

ENERGY USE PATTERNS

5.1 Why analyse building energy use?

Assessing the energy performance of a building allows you to:

1. Compare performance with standards to suggest the potential for energy saving in the building.
2. Compare with other buildings in an estate or group of buildings to help identify which should be investigated first.
3. Compare with performance in previous years to monitor progress and to assess the effect of any changes or energy saving measures.
4. Consider the energy use in more depth to help understand where energy is used and wasted, and hence where savings are most likely to be made.

A general understanding of what electricity and fuels are used for in different types of building helps to concentrate attention on priority areas, especially where the use of one of the fuels is particularly high.

5.2 Types of buildings and their energy use patterns

Universities and further education buildings have been categorised as follows: university - residential buildings, university - academic buildings, and further education buildings.

Typical energy costs per unit floor area for the three types of building are given in figure 5.1. Figures 5.2 to 5.4 show typical breakdowns of energy costs.

These examples are typical buildings. The good practice equivalents tend to use 20% to 30% less energy, mostly achieved by good management and simple measures. Still lower energy consumption is achievable in new buildings and major refurbishments.

Fossil fuels (gas, oil and coal) are used entirely for space heating, hot water generation and catering.

A large proportion of electricity use in university residential buildings is for lighting. Other uses of electricity are for hot water, catering, and domestic appliances such as televisions, stereos, fridges, cookers and kettles.

In university academic buildings and further education colleges a large proportion of the electricity use is for lighting and laboratory equipment. Electricity is used in providing domestic hot water (to a lesser extent than fossil fuels) and for office and laboratory equipment.

Figure 5.1 Typical energy costs

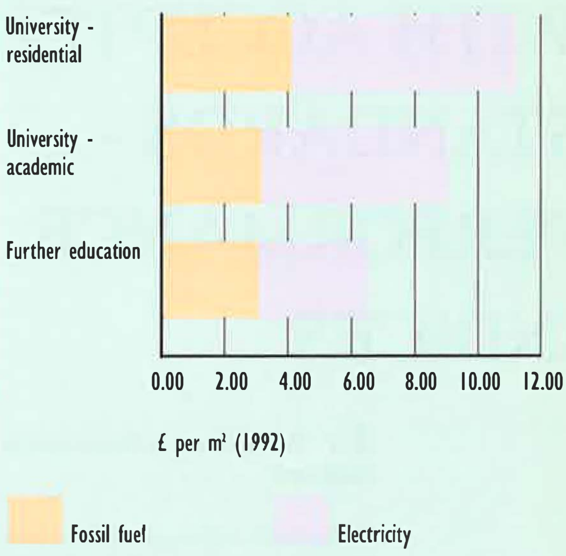


Figure 5.2 Typical energy cost breakdown in residential university buildings

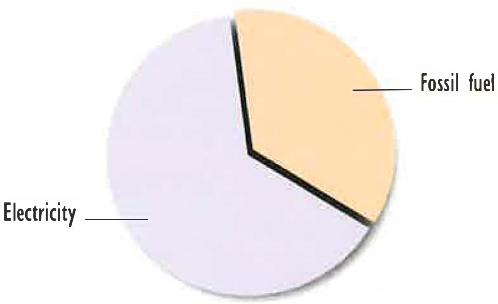


Figure 5.3 Typical energy cost breakdown in academic university buildings

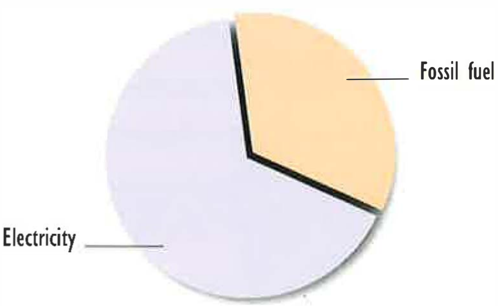
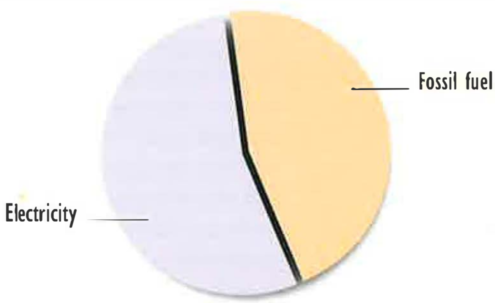


Figure 5.4 Typical energy cost breakdown for further education buildings



6

COMPARING WITH ACCEPTED STANDARDS - PERFORMANCE INDICES

6.1 Why use performance indices?

Performance indices give a measure of the energy use of a building which can be compared with the yardsticks. They can indicate the potential for improvements and can be used to show progress over time. They can also allow comparisons to be made between buildings in a group or estate.

6.2 Calculating the performance indices of a building and comparing to yardsticks

Two separate indices are calculated for the building, one for electricity and the other for fossil fuels. The separate indices should not be added together, because of the different cost and environmental impact of fossil fuels and electricity. Energy use in residential and academic buildings is significantly different. Therefore, where possible, separate performance indices should be calculated.

The performance indices are obtained by dividing the annual building or site energy use by the floor area. Yardstick values for the different building types are given in figure 6.2, with electricity consumption and fossil fuel energy consumption shown separately.

The procedure is:

1. Enter the annual energy use for each fuel into column 1 of figure 6.1.
2. Multiply each fuel by the conversion factor in column 2 to get common units of energy (kWh is used for electricity and now for gas - conversion units are given in Appendix 2).
3. Enter the treated floor area of the building in column 4.
4. Divide the energy use of each fuel by the floor area to get energy use per unit area (kWh/m^2) in column 5.
5. Add the fossil fuel figures together to get a fossil fuel index - the electricity figure can be used directly.
6. Compare the indices with yardsticks for the building type in figure 6.2 to give an energy performance assessment.

Note: this does not take account of the effect of weather on heating energy use (see section 6.4).

Annual energy consumption of your building.

This is most conveniently obtained from past bills but take care that the figures collected represent a full year and are not "estimated" by the utility. It may be helpful to look at more than one year's bills providing that there have been no significant changes to the building or its use in that time. The numbers you require are the energy units consumed, not the money value. Include all fuels: solid fuel, bottled fuel, natural gas, oil and electricity.

Floor area information.

The measure of floor area used to standardise energy consumption is treated area, defined as follows in relation to the more commonly available gross floor area:

Gross — Total building area measured inside external walls. These figures are often used by architects and quantity surveyors.

Treated — Gross area less plant rooms and other areas not heated (e.g. stores, covered car parks and roof spaces).

The best available information on floor area should be entered as either ft^2 or preferably m^2 in the form below - the estimates of treated floor area can be obtained using typical ratios as shown in the form. If more than one estimate of treated area is then available, the most reliable should be used.

	$ft^2 \div 10.76 = m^2$					Treated floor area	
Gross floor area			x	0.90	=		m^2
Treated floor area			x	1.00	=		m^2

Figure 6.1 Energy Performance Index Calculation

		Column 1 Annual Billed Units			Column 2 kWh* Conversion	Column 3 Annual kWh	Column 4 Treated floor area (m^2) divide by	Column 5 Annual kWh/m^2
Gas			kWh	x	1.0			
Oil type			litres	x				
Other Fossil fuel								
Total of fossil fuel								
Electricity			kWh	x	1.0			

Note * for kWh conversion factors see Appendix 2

There may be exceptional reasons to explain a low or high consumption. For example, a building or site may have a low consumption because of infrequent use, or a high consumption because it has laboratory equipment that uses a large amount of electricity, or extensive use is made of the facility out of hours.

Even a building with a low consumption may have opportunities for cost-effective improvement. The indices indicate which fuel requires the most attention. Section 4 shows possible energy saving measures for each energy use. The next step is to select and progress suitable measures.

6.3 Alternative yardsticks

Yardsticks based on carbon dioxide (CO_2) emissions or the cost of energy per m^2 of floor area can be used to provide a single performance index which combines fossil fuels and electricity. These can be used to prepare league tables which compare groups of buildings or to assess buildings which have fuel supply arrangements which do not fit into the yardstick categories. This may occur, for example, in buildings with electric heating or a site which uses combined heat and power (CHP).

Appendix 1 shows how to apply simple factors for CO_2 emissions or energy cost for each fuel type to calculate an overall performance index.

6.4. Refining the performance indices

If there is more information available, you may wish to assess your performance indices further in a number of ways as described in Appendix 1.

- If your site has unusual occupancy patterns, or experiences unusual weather or exposure you may want to know their likely effect.

Residential/academic combined yardsticks

Where separate energy consumption data is not available for academic and residential use, the yardsticks in figure 6.2 cannot be used directly. If this is the case, it is only possible to calculate performance indices for the site as a whole. If you know the separate areas of academic and residential buildings you can calculate a yardstick for the site to compare against the performance indices.

The procedure for calculating the site yardsticks from figure 6.2 is as follows.

1. Multiply the 'Low' consumption fossil fuel yardstick for residential buildings by residential building floor area.
2. Multiply the 'Low' consumption fossil fuel yardstick for academic buildings by academic building floor area.
3. Add the results of steps 1 & 2 to obtain a total.
4. Divide the results of step 3 by the sum of residential and academic floor areas. This figure represents the combined 'Low' consumption fossil fuel yardstick.
5. Repeat steps 1 to 4 for the 'High' consumption fossil fuel yardstick.
6. Repeat steps 1 to 5 for electricity yardsticks to obtain combined electricity yardsticks.

An example of this procedure is given in the York University case study in section 8.3

Figure 6.2 Energy Consumption Yardsticks

Performance Assessment

	Low consumption Less than	Medium Consumption Between	High consumption Greater than
	Yardsticks in kWh/m²		Yardsticks in kWh/m²
University - Residential buildings			
Fossil fuels	240		290
Electricity	85		100
University - Academic buildings			
Fossil fuels	185		220
Electricity	75		85
Further education buildings			
Fossil fuels	145		215
Electricity	35		50

- You can compare your building performance with the 'Normalised Performance Indicator' used in previous editions of these guides.

- You may wish to take account of the effect of weather when comparing buildings in different parts of the country.

7

A CLOSER LOOK AT ENERGY CONSUMPTION

7.1 Introduction

Often a fuller understanding of energy use in a building may be useful, for example after the initial measures have been undertaken, if there is a problem, if the building has poor performance or if it has unexpected energy bills. This section outlines techniques which you may find useful.

7.2 Monthly energy use

You can ask your supplier for monthly fuel data, or take monthly meter readings yourself.

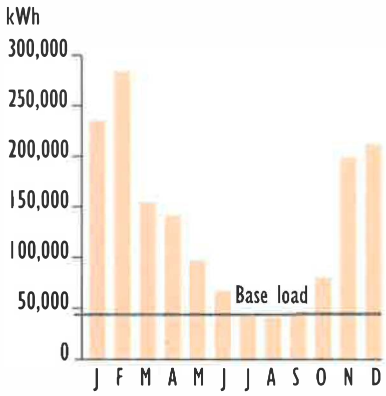
Larger sites have monthly energy bills. By looking at how these vary with the seasons some valuable insights can be obtained. Produce a monthly consumptions bar chart plot for each energy source over a year.

The billing periods should be checked. If they are not regular, some months will appear unrealistically low and others unrealistically high. This is particularly likely in December and January. If this is the case the average daily consumption for each month can be plotted to give more accuracy.

Fossil fuel consumption, used mainly for heating, should reduce greatly in summer - to zero if it is not being used for other services such as hot water or catering.

Electricity consumption should decrease in summer in a building which is not air conditioned, because of lower lighting loads. In an air conditioned building, peaks in spring and autumn may indicate simultaneous heating and cooling.

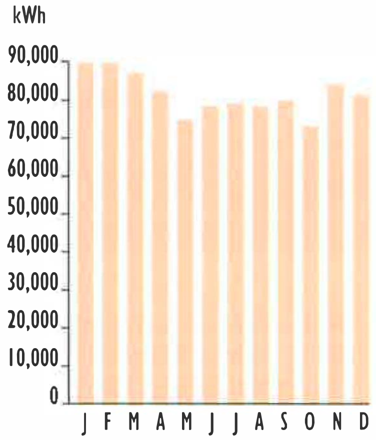
Example monthly fossil fuel use



The figure above shows the monthly fossil energy consumption of a fairly efficient university residential building which has a central boiler system for heating and hot water - the summer usage is much lower than winter usage and is at a fairly steady 'base load' level which suggests that the heating is off, though it is useful to confirm this by checking that heating pumps are off, and that pipework used solely for heating is cold.

This graph shows a base load, which helps to identify the hot water load and system losses, and the heating load which depends on the weather.

Example monthly electricity use



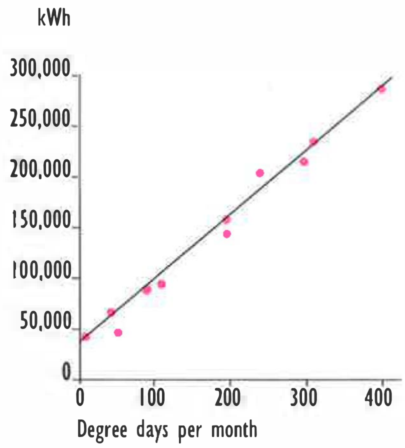
The figure above shows monthly electricity consumption for a university residential building showing a small increase in winter which may be due to increased lighting or some electric heating.

In further education buildings and some university academic and residential buildings the energy consumption will decrease significantly during vacation periods. For these buildings the consumption patterns will be different from those shown in the above graphs.

7.3 Relating heating use to weather

A fuel that is mainly used for heating should be used more in colder weather. The coldness of the weather can be expressed by a measure known as degree days. This shows by how much and for how long the outside temperature is below a control temperature (usually 15.5°C). Drawing a graph of fossil fuel consumption against the degree days for each month in the year shows how energy consuption is related to weather. Monthly figures for degree days for different areas of the country are published in the EEO's free bimonthly magazine 'Energy Management' (section 9.4).

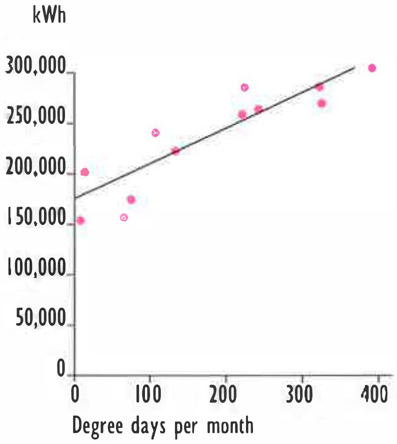
Example monthly heating energy use in a well controlled building



The building represented above has a well controlled heating system, as shown by the close fit of the points to the straight line. As the weather gets colder the energy used goes up proportionally. For this building the energy consumption falls to a small value in summer when only hot water is being provided.

A building with better insulation would have a less steep slope because energy consumption in winter would be lower.

Example monthly heating energy use in a poorly controlled building



The figure above has a large scatter of points indicating a building with poor control. The energy use in the summer months remains higher than in the previous figure, indicating that either heating is being used unnecessarily in the summer or that the boiler and hot water systems have high losses which lead to excessive waste.

For further information see:

EEO Fuel Efficiency Booklet 7. Degree Days

7.4 Adjusting energy use for weather

Once you know how weather conditions affect energy use, it is possible to allow for varying conditions. For example, it is possible to take account of the weather when comparing a building energy performance from year to year. Such comparisons show with greater accuracy the effect of any energy saving measures.

In order to adjust for weather it is necessary to know how much of the fossil energy is used for heating and how much is a steady base load. The base load can be estimated by looking at the monthly consumption of fossil energy as shown in section 7.2 or the graphs of fossil fuel against degree days as shown in section 7.3, and the rest is the energy used for space heating which varies with weather conditions.

8

CASE STUDIES

This section gives examples of buildings where energy saving measures have been implemented. The use of the Performance Index calculation is also demonstrated, both for assessing how energy efficient a building is, and as a means of evaluating the improvement in energy performance resulting from the implementation of energy saving measures.

8.1 Oxford Brookes University

The Oxford Brookes University is located on two sites: the main Gipsy Lane Campus and the Wheatley Campus. Many of the teaching facilities and residences are used out of term time for external conferences, and teaching often goes on until 21.00 throughout the whole of the year.

Owing to high maintenance and energy costs a programme of decentralising the heating system was begun in 1990. This has eliminated the high heat losses which occurred from the old rambling district heating mains, and the sites' heating systems can now be much more effectively controlled. The opportunity was taken to install over a hundred high efficiency condensing boilers as part of the new heating system in a range of buildings, including teaching blocks, student accommodation, a laundry block and a business centre.

The new heating systems have a number of features in addition to condensing boilers which increase energy efficiency:

- Optimum start/stop control to meet the requirements of staff in each building
- Sequence control - enables only the number of boilers required to meet the heat demand
- Weather compensation - the reduced temperature of the heating system in spring and autumn means that the condensing boilers operate at maximum efficiency
- Zone control in each building
- Domestic hot water systems have high capacity calorifiers - the resulting low return water temperature increases the efficiency of the condensing boilers.

All the heating systems are controlled by a central building energy management system (BEMS). This allows close monitoring and tight control which results in improved comfort and reduced energy costs.

Gas and electricity meters are installed across the site in order to allow invoicing for conferences and seminars. The meters also enable estates staff to monitor consumption trends in different parts of the site and react quickly to sudden increases in energy use.

The University has achieved major savings from the programme of decentralisation and the associated improvements in control. The condensing boilers have been a key part of this strategy.

The condensing boilers in the residential buildings will have shorter payback periods than those in the teaching buildings because they are occupied for longer.

Maintenance staff have been trained to ensure that the new condensing boilers are maintained to a high standard. The condensing boilers have not required additional maintenance compared with conventional plant. Estates staff have decided to install a further 30 condensing boilers in halls of residence.

Estimated cost savings and payback time in one of the teaching blocks

Estimated annual running cost (conventional system)	Estimated additional annual cost saving from condensing boilers	Estimated additional percentage savings resulting from condensing boilers	Overcost of condensing element boiler	Approximate payback period of the overcost of condensing boilers
£8,700	£1,370	16%	£4,800	3.5 years

Estimated economics of condensing boilers compared to all new conventional systems, the original plant having come to the end of its life.

For further information see:

EEO Good Practice Case Study 42 - Energy efficiency in higher education buildings - condensing gas boilers.

8.2 Southampton Technical College

Southampton Technical College is spread over four adjacent sites. Building types include old heavyweight brick structures, 1960s concrete and glass buildings and lightweight factory units. Total site energy bills are around £210,000 per year.

There is a variety of heating systems at the site. The main building, the Workhouse Complex, is heated by an old but well-maintained oil-fired steam system via heat exchangers in each of its four blocks. Other buildings have gas or oil-fired boilers, warm air systems, gas convectors or direct electric heaters.

In 1989 Southampton Technical College was Hampshire County Council's largest energy user. In order to achieve energy savings and gain better control of the heating systems, a building energy management system (BEMS) was installed.

"Saving energy and money was by no means the only objective. We need to be able to control conditions for students. Previously, if we saw lots of open windows we turned boilers off. Now we have full control to provide comfortable conditions and prevent that sort of thing," says the Building Maintenance Engineer.

The need was recognised for someone on site to have a thorough understanding of the BEMS.

"Buildings are very dynamic in their changing use and energy consumption depends on how they are used. So we need flexible controls and someone to work with the BEMS to respond to this. One of the reasons the BEMS works so well at Southampton is that we have the right person in control of it - someone who is interested, trained, and has an engineering background which allows him to tune the system for minimum energy use," says the Principal Energy Engineering Officer for Hampshire County Council's Architect's Department.

The BEMS includes facilities for optimum start/stop control to minimise heat-up times, frost protection, and economy control to switch off heating systems when the outside temperature reaches 15°C (above an external temperature of 15°C it was found that heating could be switched off without adversely affecting internal temperatures). It also provides weather compensation, time scheduling including daily extension scheduling and built-in yearly timetables to switch plant off during holidays. Maintenance is improved by continuously monitoring plant and flow temperatures. Standby plant such as pumps and fans are automatically changed over if failure occurs. All abnormal statuses provide an alarm to the maintenance staff.

The college operates a complex timetable involving evening classes and occasional out-of-hours functions. Scheduling plant operating times using the BEMS is considerably easier and quicker than manual methods would be.

Following the installation of the BEMS a number of other energy saving measures were implemented:

- Tungsten lighting in the staff refectory was replaced with compact fluorescent lamps to give running cost savings of 82%.
- The main steam boiler serving the Workhouse Complex was insulated with foil-backed slabs; associated pipework and valves were also insulated. This increased the efficiency of the boiler installation.
- Roof insulation was installed in lofts where it was missing or damaged.
- Cavity wall insulation was installed in buildings that did not already have it.
- Suspended ceilings were fitted to corridors to reduce their internal height from 6m to 3m. This reduced the volume of air to be heated. The new ceiling incorporates panels of twin-walled polycarbonate material which allows some natural daylight from existing rooflights to penetrate.
- External doors and windows have been draught stripped.

"The measures, particularly the draught stripping, have definitely improved comfort conditions as well as reducing energy consumption" says the Building Maintenance Engineer.

Attention is now being given to monitoring energy bills and targeting future consumption. The site includes a lot of sub-meters which are read monthly. These help pinpoint buildings or departments which are the largest energy users, so that future action can be effectively targeted.

Improvement in performance

	1989	1993
Treated floor area (m^2)	24,124	31,006
Fossil fuel consumption (kWh)	5,232,496	5,729,909
Fossil fuel performance index (kWh/m^2/yr)	217	185
Percentage reduction		15%
Electricity consumption (kWh)	1,575,297	1,674,324
Electricity performance index (kWhm^2/yr)	65	54
Percentage reduction		17%

8.3 University Of York

An energy audit carried out by a consultant in 1980 found that energy accounted for about 6% of the total spending budget. This has been reduced to around 2% through actively controlling energy use.

The results of the 1980 energy audit were presented to the University Bursar, who realised that a formal structure was required to act upon the long term investment strategy recommended in the consultant's report. He established The Energy Conservation Committee which included himself and technical and academic staff. This gives its recommendations more weight than if they came from individual officers. An energy manager was appointed in 1984.

Energy Saving Measures

Improvements to building structures, lighting systems, upgrading of heating controls, and draught stripping and replacement of plant with more efficient versions have been instigated. A series of measures specific to science laboratories have also been taken:

- Plant growth cabinets in the Biology Department were found to be using vast amounts of energy. With the co-operation of departmental staff, more efficient lighting was installed and new controls were developed to prevent simultaneous heating and cooling.
- Improved controls have been fitted to Chemistry Department fume cupboards. The new controls detect the opening of cupboard sashes and automatically modulate the supply and extract air system in relation to the position of the sashes.

A building energy management system (BEMS) has also been installed which enables the energy manager to control plant efficiently. The BEMS cost £15,000 and saves an estimated £4,000 pa.

Departmental Responsibility for Energy Use

The University has now made each academic department responsible for the cost of their own energy use. Departmental staff, with their understanding of the needs of research being carried out, were able to limit the use of equipment and cut electricity use without damaging research work. But before, it was common to find electrical research equipment switched on continuously. By the third year of the new policy staff had started to realise the benefits of examining and rationalising their own energy use.

Early easy measures gave quick and visible results and so built up credibility for the Energy Conservation Committee. At York, the involvement of staff in each department has been vital to the success of the programme. Progress is monitored in the University newsletter. A series of energy fact sheets have also been written and distributed to departments.

Combined residential/academic yardsticks

At York University there is a district heating scheme which provides space heating to both academic and residential buildings. It is difficult therefore to apportion fossil fuel use between academic and residential sites. Performance indices and yardsticks combining academic and residential areas therefore need to be generated, as discussed in section 6.2.

The example is for the 'low consumption' fossil fuel yardstick and illustrates the method for determining a combined yardstick.

Treated residential floor area $=61,787\ m^2$

Treated academic floor area $=84,143\ m^2$

Low consumption fossil fuel yardstick for residential buildings (see section 6.2) $=240\ kWh/m^2$

Low consumption fossil fuel yardstick for academic buildings (see section 6.2) $=185\ kWh/m^2$

Combined yardstick for York University

$$=\frac{(84,143 \times 185)+(61,787 \times 240)}{84,143 + 61,787} = 208\ kWh/m^2$$

Energy Savings

Although the energy bill is still high at £800,000 pa, it has been reduced considerably from its 1980 levels. Cumulative energy savings now amount to £1.3 million for a total capital outlay of £1 million. Current energy savings are running at around £170,000 a year for a campus-style establishment which has 30 main buildings and 5,000 students.

The following table gives the combined yardsticks for York University:

Performance assesment

Combined yardsticks for York University in kWh/m^2

	Low consumption Less than		Medium consumption Between		High consumption More than
York University - Residential and academic buildings	——►	◄——	——►	◄——	
Fossil fuels		208		250	
Electricity		79		92	

Performance indices for 1992/93

Fossil fuel index ($kWh/m^2/yr$)	Fossil fuel performance assessment	Electricity index ($kWh/m^2/yr$)	Electricity performance assessment
299	High consumption	92	Medium consumption

9

ADVICE AND HELP

9.1 The Energy Efficiency Office

The Energy Efficiency Office (EEO) is part of the Department of the Environment.

The EEO currently aims to achieve environmental and economic benefits by promoting cost effective energy efficiency measures in the industrial, commercial, domestic and public sectors of the economy by:

- Raising awareness
- Identifying and overcoming barriers to action
- Providing financial incentives where appropriate
- Regulation where necessary
- Providing technical advice.

9.2 Best Practice Programme

The EEO's Best Practice programme gathers and disseminates authoritative information on cost effective energy saving measures. The Best Practice programme for buildings is managed on behalf of the EEO by the Building Research Energy Conservation Support Unit (BRECSU) and for industry by the Energy Technology Support Unit (ETSU).

A range of publications is available under the Best Practice programme, normally free of charge. Relevant titles for further education and university buildings are listed here.

Good Practice Guides give advice on how to implement energy saving measures. Titles available relating to further education and university buildings are:

35 Energy efficient options for refurbished offices - for the design team
46 Heating and hot water systems in offices
84 Managing and motivating staff to save energy

General Information Leaflets and Reports also give advice on how to implement energy saving measures. General Information Leaflets relating to further education and university buildings are:

1 The success of condensing boilers in non-domestic buildings. A user study

7 Energy efficiency in schools and colleges.

Information on energy management is contained in these General Information Reports:

12 Organisational aspects of energy management

13 Reviewing energy management

14 Energy management of buildings including a review of some case studies.

Good Practice Case Studies provide examples of proven techniques which are already enabling the better energy users to be more energy efficient. Titles relating to further education and university buildings are:

42 Energy efficiency in higher education buildings - condensing gas boilers.

Fuel Efficiency Booklets are working manuals which provide detailed technical guidance on specific areas of energy use in buildings and industry. Relevant booklets are:

1 Energy audits for buildings
7 Degree days
8 The economic thickness of insulation for hot pipes
9 Economic use of electricity in buildings
10 Controls and energy savings
12 Energy management and good lighting practices.

In addition, a wide range of events is organised to promote the results of the Best Practice programme. These include seminars, workshops and site visits and are targeted at different sectors and professionals.

Details of publications and events can be obtained from:

BRECSU (for buildings)
Building Research Establishment
Garston
Watford WD2 7JR
Tel: 0923 664258
Fax: 0923 664097

ETSU (for industrial technologies)
Harwell
Didcot
Oxon OX11 ORA
Tel: 0235 436747
Fax: 0235 432923.

9.3 Other publications available from BRECSU

Energy Efficient Lighting in Buildings (1992). A THERMIE Maxibrochure.

9.4 Free Publications From the EEO

The Introduction to Energy Efficiency series. There are 13 Guides in this series, of which this is one:

Catering establishments
Entertainment buildings
Factories and warehouses
Further and higher education
Health care buildings
Hotels
Museums, galleries, libraries and churches
Offices
Post Offices, banks, building societies and agencies
Prisons, emergency buildings and courts
Schools
Shops and stores
Sports and recreation centres

Choosing an Energy Efficiency Consultant (EMAS 2)

Practical Energy Saving Guide for Smaller Businesses (ACBE 1)

The above are all available from:

Department of the Environment
Blackhorse Rd
London SE99 6TT
Tel: 081 691 9000

The 'Energy Management' journal. Published bi-monthly and available from the EEO.
Tel: 071 276 6200.

9.5 Other EEO Programmes

Making a Corporate Commitment Campaign

The 'Making a Corporate Commitment' campaign seeks board level commitment to energy efficiency. It encourages directors to sign a Declaration of Commitment to responsible energy management, prepare a business plan for energy efficiency and ensure that it becomes an item that is considered regularly by their main board.

Publications:

Chairman's Checklist
Executive Action Plan
Energy, Environment and Profits - Six case studies on corporate commitment to energy efficiency.

Further information is available from the Campaign Offices on
071 276 4613.

9.6 Sources of Free Advice and Information

Regional Energy Efficiency Officers

11 Regional Energy Efficiency Officers (REEOs) around the UK can provide copies of all the EEO's literature and give specific advice on:

- opportunities for better energy efficiency in your organisation
- technologies and management techniques you should be thinking about
- appropriate sources of specialist advice and assistance in the private sector
- EEO programmes
- regional energy managers' groups.

REEO Northern Region
Wellbar House
Gallowgate
Newcastle Upon Tyne NE1 4TD
Tel: 091 201 3343

REEO Yorkshire and Humberside
City House
New Station Street
Leeds LS1 4JD
Tel: 0532 836 376

REEO North West
Sunley Tower
Piccadilly Plaza
Manchester M1 4BA
Tel: 061 838 5335

REEO East Midlands
Cranbrook House
Cranbrook Street
Nottingham
Nottinghamshire NG1 1EY
Tel: 0602 352 292

REEO West Midlands
Five Ways Tower
Frederick Road
Birmingham B15 1SJ
Tel: 021 626 2222

REEO Eastern
Heron House
49-53 Goldington Road
Bedford MK40 3LL
Tel: 0234 276 194

REEO South West
Tollgate House
Houlton Street
Bristol BS2 9DJ
Tel: 0272 878 665

REEO South East
Charles House
Room 565
375 Kensington High St
London W14 8QH
Tel: 071 605 9160

REEO Scotland
New St Andrews House
Edinburgh
Scotland EH1 3TG
Tel: 031 244 4662

REEO Wales
Cathays Park
Cardiff
Wales CF1 1NQ
Tel: 0222 823 126

REEO Northern Ireland
Dept of Economic Development
Netherleigh House
Massey Avenue
Belfast
N Ireland BT4 2JT
Tel: 0232 529900.

9.7 Other Programmes

Energy Design Advice Scheme

The Energy Design Advice Scheme is a Department of Trade and Industry discretionary initiative aimed at improving the energy and environmental performance of the building stock by making low energy building design expertise more accessible for the energy efficient design and refurbishment of buildings. The scheme offers support, via a number of Regional Centres, to design teams or clients in the energy aspects of design of new buildings or refurbishment projects over 500m^2 gross area.

Further information can be obtained from the following Regional Centres:

For Scotland
Tel: 031 228 4414

For South East England
Tel: 071 916 3891

For Northern England
Tel: 0742 721 140

For Northern Ireland
Tel: 0232 364 090.

EU Programmes

Several EU programmes aimed at demonstrating energy efficiency measures and encouraging energy efficiency R&D. Details change periodically. For further information contact BRECSU for buildings and ETSU for industry.

9.8 Other Publications

Chartered Institution of Building Services Engineers (CIBSE):

CIBSE Applications Manual, AM 5:1991, Energy Audits and Surveys

CIBSE Applications Manual, AM 6:1991, Contract Energy Management

CIBSE Applications Manual, AM3, Condensing Boilers

CIBSE Applications Manual, AM8, Private and Standby Generation of Electricity

CIBSE Code for Interior Lighting (1984)

CIBSE Lighting Guide 3(LG3)(1989). Areas for Visual Display Terminals.

Available from:

CIBSE, 222 Balham High Rd,
Balham,
London SW12 9BS.
Tel: 081 675 5211
Fax: 081 675 5449.

Heating and Ventilating Contractors Association (HVCA):

Standard Specification for Maintenance of Building Services. Volumes 1 - 5. 1990 - 1992.

Available from:

HVCA Publications, Old Mansion House, Earmont Bridge, Cumbria,
CA10 2BX
Tel: 0768 64771.

9.9 Other Useful Addresses

Energy Systems Trade Association Ltd (ESTA)
PO Box 16, Stroud, Gloucestershire
GL6 9YB
Tel: 0453 886776
Fax: 0453 885226

Major Energy Users' Council
10 Audley Road
London W5 3ET
Tel: 081 997 2561/3854
Fax: 081 566 7073.

APPENDIX 1

Development of Building Performance Indices (PI)

Introduction

This section outlines how to calculate environmental and cost indices for the energy used in your building or site. It describes the effect of weather, building occupancy and exposure on the performance of a building, with a method to allow for these factors if required.

Adjustments of the PI for these factors produces a 'Normalised Performance Index' (NPI) which is compatible with earlier versions of this guide. For many purposes, the effect of these factors on performance indices is small enough to be ignored.

Figure A1.1
CO_2 Performance Index Calculation

	Column 1 Annual energy use kWh/m²	Column 2 CO_2 conversion* factors kg/kWh	Column 3 Annual CO_2 emissions kg/m²
Gas		x 0.20	
Oil		x 0.29	
Coal		x 0.32	
Electricity		x 0.70	
Total CO_2 emissions per m²			

*typical 1993 emission factors

Figure A1.2
Cost Performance Index Calculation

	Column 1 Annual energy use kWh/m²	Column 2 Cost conversion factors £/kWh*	Column 3 Annual cost £/m²
Gas		x 0.014	
Oil		x 0.012	
Coal		x 0.009	
Electricity		x 0.071	
Total energy cost per m²			

*typical 1992 prices

Overall performance indices

Overall performance indices provide a single measure of building performance, and can be expressed in terms of carbon dioxide (CO_2) emissions or energy cost. Overall energy indices are useful for comparing a stock of buildings or for assessing the performance of buildings with electric heating or combined heat and power (CHP). However, separate fossil fuel and electricity performance indices are more useful to assist in deciding a course of action.

To calculate overall performance indices you need the annual energy use indices as obtained in figure 6.1 and conversion factors for each of the fuels - some of which are given in figures A1.1 and A1.2. The calculation procedure is to enter the kWh/m² figure in Column 1, and multiply by the relevant conversion factors in column 2 to get either the kg of CO_2 per m² or the cost per m² in column 3.

The conversion factors shown are broadly representative of the current fuels used at further and higher education sites, and can be used if a consistent set of factors is required. CO_2 factors, particularly for electricity, may vary from this data. Cost factors will also vary over time and as a function of use. Energy unit costs in larger buildings tend to be cheaper than for smaller supplies. You may wish to use your own costs from your own bills instead of those given here.

Overall yardsticks for CO_2 emissions or energy costs can also be calculated, by inserting yardstick energy consumptions (given in figure 6.2) into column 1. These can be compared with the actual index for your building to give an overall assessment. CO_2 and cost yardsticks calculated on the basis that the fossil fuel is gas are presented in figure A1.3.

Effect of weather on energy use

Weather changes from year to year for a given site cause variations in fossil/heating energy use of typically ±5% from the average values or ±10% in more extreme years.

Weather differences across the country cause variation in heating requirements of typically ±10% from average values and ±20% in more extreme areas.

The effect on electricity use will be small unless electricity is used for space heating, or in air conditioned buildings where the cooling energy will be higher during a warm summer.

Exposure

If a building is very exposed (on an exposed hill for example), heating energy increases by 5-10% and likewise a completely protected building may use 5-10% less. In many cases steps will have been taken on exposed buildings to improve draught sealing which will offset the increase. Electricity use is largely unaffected except in electrically heated buildings.

Hours that the building is occupied (occupancy)

Occupancy affects buildings' energy use in different ways for different systems. Heating energy in a naturally ventilated heavy building varies very little with occupancy - say 5%. If a building has a light weight structure, or is mechanically ventilated or air conditioned, the heating energy may increase in more direct proportion to the occupied hours, giving 20% variation or more from the typical occupancy.

Electricity consumption of a badly controlled building will be almost

Figure A1.3 Carbon dioxide and cost yardsticks

CO_2 Performance Assessment

	Low Emissions Less than	**Medium Emissions** Between	**High Emissions** Greater than
Building Type	Yardsticks in kg CO_2/m^2		Yardsticks in kg CO_2/m^2
1. University - residential	110		130
2. University - academic	90		105
3. Further education	55		80

Cost Performance Assessment

	Low Cost Less than	**Medium Cost** Between	**High Cost** Greater than
Building Type	Yardsticks in £/m²		Yardsticks in £/m²
1. University - residential	9.4		11.2
2. University - academic	7.9		9.1
3. Further education	4.5		6.6

CO_2 and cost yardsticks are based on factors given in figures A1.1 & A1.2

independent of the occupancy, owing to lights and services left on from early morning to last thing at night. But for a well controlled building, both lights and plant may operate in direct proportion to occupancy.

Normalised performance indices

It is possible to adjust (normalise) performance indices for weather, exposure and extended occupancy, but care is needed as incorrectly applied adjustments, or adjustments that are too simplistic, may introduce larger errors than the typical variations discussed above. For example, the effect of extended hours of use on energy consumption can easily be exaggerated, making the building performance seem better than is really the case.

Note also that while a normalised performance index is a better measure of a building's efficiency than an unnormalised index, the latter shows the building's actual performance. So a building with a low normalised performance index, but a high performance index before adjustment, is efficient, but since it is still a high user of energy, it may well offer good opportunities for cost effective energy saving.

The worksheet in figure A1.4 can be used to obtain performance indices which are normalised to standard conditions of weather, exposure and occupancy. This is useful if:

- You require normalised performance indices for compatibility with previous work
- Any of the factors cause significant errors (see above sub sections to evaluate this).

A normalised performance index based on overall CO_2 emissions or energy cost is obtained by using figure A1.1 or A1.2 and inserting the normalised performance indices for each fuel into Column 1. If more than one fuel is used for heating, calculate a separate normalised performance index for each fuel first and then use this procedure.

Performance indices - summary

- Simple performance indices are for initial energy assessments. Separate performance indices are calculated, one for fossil fuels and one for electricity use, and no adjustments are made.
- Overall performance indices, based on carbon dioxide (CO_2) or cost, are normally used when the energy supply arrangement is not typical or when a number of buildings are to be compared. Also, you may want to know the cost or the CO_2 performance for a single building.
- Normalised performance indices are used when more sensitive comparisons are required and the effect of factors such as weather and occupancy become significant. But if you choose to normalise, be aware of introducing errors.

Figure A1.4 Normalised Performance Indices calculation

	Fossil fuel: Gas	Fossil fuel: Oil	Fossil fuel: Other		Total of Fossil Fuels	Electricity
Total energy consumption (kWh)				(A)		
Space heating energy (kWh)				*(B)		
Non space heating energy (kWh)				A-B = (C)		
Find the degree days for the energy data year				*(D)		
Weather correction factor = 2462 ÷ D =				(E)		
Obtain the exposure factor below				*(F)		
Obtain occupancy factor for heating energy use from below				*(G)		
Annual heating energy use for standard conditions				BxExFxG = (H)		
Obtain occupancy factor for non-heating energy from below				*(K)		
Annual non-heating energy use = C x K =				(L)		
Normalised energy use = H + L =				kWh (M)		
Find floor area				m² (N)		
Find the Normalised Performance Indices = M ÷ N =				kWh/m² (P)		

* Notes:
(B) Estimation of weather-dependent heating energy use is discussed in section 7.
(D) For degree day information, see Fuel Efficiency Booklet 7 - Degree Days
Monthly degree day figures are published in 'Energy Management' (see section 9.4)
(F) Exposure factors from figure A1.5.
(G) and (K) Occupancy factors from figure A1.6.

Figure A1.5 Exposure factor

	Factor
Sheltered. The building is in a built-up area with other buildings of similar or greater height surrounding it. This would apply to most city centre locations.	1.1
Normal. The building is on level ground in urban or rural surroundings. It would be usual to have some trees or adjacent buildings.	1.0
Exposed. Coastal and hilly sites with little or no adjacent screening.	0.9

Figure A1.6 Occupancy Factors

(Not available for residential buildings)	Factor for heating energy (G)	Factor for non-heating energy (K)
Normal building occupancy for teaching buildings: (5 days, 10 hours per day)	1.00	1.00
Lightweight building Extended occupancy	0.85	0.80
Other buildings Extended occupancy	0.95	0.80

APPENDIX 2

Energy Conversion Factors

The unit of energy used in this guide is the kilowatt - hour (kWh). One kilowatt - hour is consumed by a typical one bar electrical fire in one hour. For fuels which are metered in other units, multiply the metered value by the relevant conversion factor from the following table to obtain the value in kWh.

Figure A2.1 Conversion to kWh

	kWh conversion
Light Fuel Oil	11.2 kWh/litre
Medium Fuel Oil	11.3 kWh/litre
Heavy Fuel Oil	11.4 kWh/litre
Gas Oil (35 second)	10.8 kWh/litre
Kerosene - burning oil 22 second	10.4 kWh/litre
Electricity	[Metered directly in kWh]
Natural gas	29.31 kWh/therm
Liquid Petroleum Gas (LPG) (Propane)	6.96 kWh/litre
Coal (washed shingles)	7,900 kWh/tonne
Coal (washed smalls)	7,800 kWh/tonne

BEST PRACTICE PROGRAMME

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